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Seventh Workshop on Seedling Physiology and Growth Problems in Oak Plantings
(Abstracts)

D. D. McCreary and J. G. Isebrands

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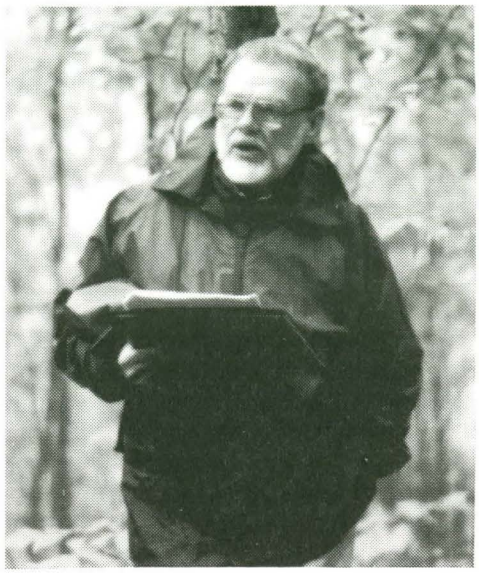
Dedication and Preface

Paul S. Johnson



Edward F. Loewenstein

This General Technical Report (GTR) is dedicated to Dr. Paul S. Johnson, a Research Forester from the North Central Research Station in Columbia, MO. In 1979, Johnson led an effort to initiate the first workshop on seedling physiology and growth problems in oak plantings in Columbia, MO (GTR-NC-62). The impetus behind the forum was an increased interest among North American Foresters in planting oak. Johnson's goal was to get together a small group of interested foresters, forest scientists, tree physiologists, and horticulturists every few years to informally exchange ideas on: (1) physiology and genetics, (2) seedling propagation and production, and (3) field performance of oaks. Through the years the interest in planting oak has continued, and so have the workshops, keeping the original goal of a small informal group. The second workshop was held in 1983 in Starkville, MS (GTR-NC-99); the third in 1986 in Carbondale, IL (GTR-NC-121); the fourth in 1989 in Columbus, OH (GTR-NC-139); the fifth in 1992 in Ames, IA (GTR-NC-158); the sixth in 1995 in Rhinelander, WI (GTR-NC-182); and the seventh and latest in 1998 in South Lake Tahoe, CA. Abstracts of those 1998 papers are presented here. This report is dedicated to one of the masters of oak silviculture, Dr. Paul S. Johnson. We thank him for his many outstanding contributions to oak silviculture throughout his career.

ACKNOWLEDGMENTS

Doug McCreary and Jud Isebrands, workshop coordinators, wish to gratefully acknowledge the invaluable assistance of Joni Rippee and Jerry Tecklin with the planning and arrangements for the meeting, and Don Thane, Dave Parmenter, and Mark Hicks for assisting with the field trip. Workshop participants are grateful to Doug McCreary and the University of California for inviting us all to California for the seventh workshop in 1998.

REVIEW PROCEDURE

Each abstract in this general technical report was critically reviewed by at least two editors. Revised abstracts were reviewed by each author and then submitted camera-ready to North Central Research Station, USDA Forest Service, for publication. Individual authors are ultimately responsible for the accuracy of their papers.

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REGENERATION OF NATIVE CALIFORNIA OAKS ON HARDWOOD RANGELANDS

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Since the turn of the century, there have been reports that the natural regeneration of several species of native California oaks, including blue oak (*Q. douglasii* H. & A.), valley oak (*Q. lobata* Nee), and Engelmann oak (*Q. engelmannii* Greene), is inadequate to sustain their populations. These species are deciduous white oaks, endemic to the State, that grow primarily in the foothills or lower elevation valleys—areas also referred to as hardwood rangelands. The causes of poor regeneration are complex and varied, and the primary factors responsible at one location may be different at another. Cattle grazing, deer and rodent herbivory, acorn depredation, insect defoliation, and severe competition from annual grasses have all been identified as factors limiting regeneration success. These same factors can also hinder attempts to regenerate oaks artificially.

To help develop guidelines for successfully artificially regenerating native California oaks, various research projects have been conducted at the University of California's Sierra Foothill Research and Extension Center. Several studies have examined acorn collection, handling, storage, and planting. Results indicated that for blue oak, acorns can be collected over quite a wide interval, extending from late August until late October. Acorns from all harvest dates had high germination as long as they were not allowed to dry out before storage. Soaking acorns for a day prior to storage had little effect. However, a 10 percent decrease in moisture resulted in 40 percent less germination.

Removing weeds and protecting acorns and seedlings from animals have also been found to be critical for regeneration success. In a recent study, various sizes of weed-free zones were compared. Results indicated that seedling height and diameter were strongly related to the diameter of the weeded areas. In this same trial, we also examined the field performance of seedlings protected with tree shelters and found that seedlings in shelters had higher survival, more flushes, taller growth, and more resistance to attack from various animals.

These and other studies suggest that native California oaks can be successfully regenerated if sufficient attention is paid to maintaining the physiological quality of the acorns and/or seedlings, planting them properly, and protecting and maintaining them in the field.

REGENERATION OF NATIVE CALIFORNIA OAKS IN THE FOREST ZONE

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The two native California oaks in the forest zone of California are California black oak (*Quercus kelloggii* Newb.) and tanoak (*Lithocarpus densiflorus* [Hook. and Arn.] Rehd.). Both are ancient species with many adaptations to withstand California's Mediterranean climate, but some weaknesses as well. Both sprout vigorously from the root crown and both produce copious amounts of acorns. Sprouting has been the primary reproduction mode of approximately 90 percent of trees in existing stands. Research on oak regeneration and seedling physiology has been limited and sporadic. No major research program has been active for the last decade, although some plantings have been attempted for wildlife and recreation purposes.

Past research has documented the gain in speed and completeness of germination from point-up versus point-down acorns, the development of a long (30-inch) taproot the first growing season, the early propensity of tanoak seedlings to die back and become seedling-sprouts, and the density and development of seedling-sprouts of both species. Some manipulation of root-crown sprouts and the effect on growth and form also has been done.

Research also has shown that neither species can be established in conventional plantations in clearcuts using direct-seeded germinated acorns of tanoak and germinated acorns and container-grown seedlings (plugs) of California black oak. Irrigation, fertilizer, and shading aided tanoak survival and growth but were insufficient for establishment. Fertilizer aided black oak more than tanoak, but it too did not lead to satisfactory growth or sapling form.

It is sad that we do not know how to achieve consistent and reliable seedling growth. We suspect that shoot growth is delayed until enough water-absorbing roots are present to gather adequate soil moisture and nutrients. Shade at some level also is required. Early close-spacing probably will be needed to provide shade and straight stems.

A field test of California and Missouri regeneration techniques is planned. The California method will stress development of a seedling taproot system versus the Missouri system that emphasizes fibrous roots.

EFFECTS OF FIRE ON NATURALLY OCCURRING BLUE OAK (*QUERCUS DOUGLASII*) SAPLINGS AND PLANTED VALLEY OAK (*Q. LOBATA*) SEEDLINGS

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Fire plays an important role in the maintenance of numerous plant communities in California, but little is known about the role of fire in the sustainable management of California oak woodlands. In a previous study on blue oak (*Quercus douglasii* H. & A.) sapling recruitment in 15 locations, we found that sapling recruitment was not dependent upon fire and that repeated fires reduced sapling populations.

We studied the survival and regrowth of naturally occurring blue oak saplings burned in a September 1996 arson fire in Vacaville, California. The saplings (pre-fire height 33-353 cm) were located in a mesic, non-grazed mixed oak woodland with an annual grassland understory and numerous old clearings. Fire fuels consisted of dry grass and other herbaceous residues, which were completely consumed in the rapid, low-moderate intensity fire. No mature trees were killed and very little visible trunk scarring developed after the fire.

Of 67 saplings surveyed, 6 percent were completely killed by fire. All of the mortality occurred in saplings less than 100 cm tall. Almost all saplings less than 150 cm tall and/or with basal diameters of less than 5 cm were completely topkilled. About 8 percent of the topkilled saplings (pre-fire heights < 75 cm) had regrown to their pre-fire shoot height by May 1998, but shoot diameter and total shoot biomass of all topkilled saplings were still well below pre-fire levels. Among partially topkilled saplings, only 2 of 11 showed improvement in live crown ratings by May 1998 and one died back to root-sprouts between June 1997 and May 1998. Contrary to speculations in the literature based on dendrochronological studies, we found that partial or complete topkill from fire does not confer any growth or survival benefits to blue oak saplings under the conditions in our study.

We also studied early growth and survival of valley oak seedlings (*Quercus lobata* Nee) planted in burned and unburned open sites 2 months after the aforementioned fire. Acorns were direct-seeded into sites prepared by turning over soil with a shovel. Sites were mulched with chipped pruning waste but were not protected, irrigated, or fertilized. Herbaceous cover within the burn area reestablished rapidly during the winter of 1996-1997 and was equivalent to unburned areas by the following winter. May 1998 survival of emerged seedlings (83 percent overall) and seedling height (average 14 cm) did not differ significantly between burned and unburned sites.

THE EFFECT OF INSECTICIDE APPLICATIONS ON ACORN QUALITY IN NORTHERN RED OAK (*QUERCUS RUBRA* L.)

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Weevils of the *Curculio* spp. consume the cotyledonary tissue of maturing northern red oak (*Quercus rubra* L.) acorns. Weevil damage reduces the number of viable acorns available for nursery planting if significant portions of cotyledons are destroyed. In addition, some seedling attributes such as height can be affected by the amount of cotyledonary tissue an acorn has at planting time. Protection of acorn crops from insect depredation would increase the number of viable acorns for planting by reducing cotyledon damage within each acorn, resulting in more seedlings with better growth. A study was designed to evaluate the effectiveness of an insecticide on controlling weevil damage on two trees in a northern red oak seedling seed orchard. Each tree was divided in half using polyethylene tarps. An insecticide, Capture®, was applied to one half of each tree, and the other half was used as a control (unsprayed). The trees were sprayed every 3 weeks. After maturation, the acorns were collected, dissected, and evaluated for insect damage. Results indicated that acorns on the sprayed side had a greater amount of healthy cotyledon tissue than the acorns from the control side. Capture® was effective in protecting acorns from weevil infestation, but it did not protect the acorns from any other damaging agents classified, such as the stony gall wasp (*Callirhytis fructuosa* Weld.). These other damaging agents, however, have not significantly affected acorn yields in this specific orchard.

FIRST-ORDER LATERAL ROOTS: BASIC BIOLOGY AND IMPLICATIONS FOR ARTIFICIAL REGENERATION OF *QUERCUS* STANDS

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The near total annihilation of American chestnut (*Castanea dentata*) by chestnut blight (*Cryhonectria parasitica* (Murrill) Barr) early this century resulted in large thriving oak forests in many areas of the eastern United States. These oak forests have been easy to maintain on the less productive sites (site index < 21 m age 50) but have been rapidly declining on the most desirable and productive mesic sites (site index > 23 m age 50). Regenerating these productive sites using technology developed for the poor sites has not been generally successful. This problem has raised concern within the forestry community that such valuable oak species as northern red oak (*Quercus rubra* L.) and white oak (*Q. alba* L.) may eventually disappear as viable and renewable components of the deciduous forests of the Eastern United States if we rely entirely upon natural regeneration for stand renewal.

Extensive testing of *Quercus* species in various nursery trials indicates that based upon first-order lateral root (FOLR) numbers and competitive capacity exhibited in the nursery, only about 50 percent of germinated acorns may result in seedlings capable of competing successfully in the forest. A predictive procedure using mean seedling heights, root collar diameters, and FOLR numbers is being tested that permits rapid assessment of bare root nursery stock. Data obtained from tests with individual half-sib progeny of specific *Quercus* species indicate that all progeny exhibit a similar relationship between FOLR development and percentage of competitive seedlings grown in the nursery. Field performance of outplanted individual seedlings with above average FOLR numbers has been great, and seedlings have remained competitive for up to 8 years with a minimum cultural release. The selection criteria have proven very successful in establishing potential oak seed orchards, with individual tree heights of > 5 m being obtained by age four. First-year northern red oak acorns have been observed in these orchards by age five.

PHOTOSYNTHETIC CHARACTERISTICS OF FIRST-YEAR NURSERY-GROWN OAK SEEDLINGS

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Acorns of northern red oak (NRO, *Quercus rubra* L.), Shumard oak (SO, *Q. shumardii* Buckl.), and white oak (WO, *Q. alba* L.) were sown and grown in the Whitehall Experiment Forest Nursery (Athens, GA) in January 1998. All acorns were collected in Georgia except that NRO acorns were collected from Wisconsin and Georgia. In February 1999, seedlings were transplanted to test the feasibility of enrichment planting with quality seedlings in small cleared forest areas in the South. Some Wisconsin NRO seedlings were planted under red pine stands in Wisconsin in May 1999.

The Wisconsin NRO seedlings grew faster than the Georgia NRO seedlings from June through mid-August. In mid-September, most of the Wisconsin NRO seedlings formed tight buds, whereas most of the Georgia NRO seedlings were still in active flush growth. The SO seedlings grew as fast as the Wisconsin NRO seedlings in early summer, but slowed down in September. Growth of WO seedlings was the slowest of all oaks, but they were still actively growing in September.

During August 1998, photosynthetic characteristics for these oaks were determined using a portable, open-system, infrared CO_2 analyzer (LiCor 6400). All measurements of net photosynthetic rate (Pn) were made at 1600 μmol per square meter per second. The greatest Pn occurred between 9 a.m. and noon for all oaks. No obvious midday depression in this rate was observed, except that the Pn of the Wisconsin NRO seedlings decreased by 25 percent between 1 and 3 p.m. Decreases in Pn for all oaks were observed after 5 p.m. The maximum Pn, obtained throughout August from the Georgia NRO, SO, and WO seedlings, was, respectively, 11, 13, and 13 μmol CO_2 per square meter per second. The maximum Pn for Wisconsin NRO seedlings decreased from 19 μmol in early August to 14 μmol CO_2 per square meter per second in late August. Light compensation points for the Wisconsin NRO, Georgia NRO, SO, and WO seedlings were 18, 23, 17, and 12 μmol per square meter per second, respectively. Photosynthetic photon flux densities required for half of the maximum Pn were 255, 233, 167, and 166 μmol photons per square meter per second, respectively, for the Wisconsin NRO, Georgia NRO, SO, and WO seedlings. Although WO is as active photosynthetically as NRO and SO, its smaller leaf size and fewer number of leaves might contribute to its slower growth than other oaks. The faster growth of the Wisconsin NRO seedlings in early summer is partially due to their higher Pn as compared to that of Georgia NRO seedlings.

FORCING ENVIRONMENT AFFECTS EPICORMIC SPROUT PRODUCTION OF NORTHERN RED OAK AND WHITE OAK FOR VEGETATIVE PROPAGATION

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The purpose of this study was to test whether different forcing environments affect the number and quality of epicormic sprouts forced on dormant branch segments of adult trees. In the spring of 1997 and 1998, one to four basal branches were removed from three white oak (*Quercus alba* L.) trees and three northern red oak (*Q. rubra* L.) trees, plus the main stem from three other white oaks. Branches and stems were cut into 24-cm-long segments and placed horizontally in 1,040 plastic trays filled with moist perlite medium. Seven different greenhouse forcing environments were tested: (1) water daily with 5 cm of water and allow medium to drain, (2) water daily with 5 cm of water and keep medium flooded 1 cm deep, (3) mist daily with 10 cm of water in 45 minutes and allow medium to drain, (4) mist daily with 10 cm of water in 45 minutes and keep medium flooded 1 cm deep, (5) place inside a humidity tent and water medium every other day, (6) cover trays with humidity domes and water medium every other day, and (7) place on shaded bench and mist medium for 6 seconds every 8 minutes during daylight hours. Epicormic sprouts from 5 to 30 cm long were cut into 5- to 10-cm-long softwood cuttings. The basal 2 cm of each cutting was dipped for 15 to 20 minutes in one of six aqueous dilutions of Dip 'n Grow (1% IBA and 0.5% NAA). Treated cuttings were stuck in 1 to 1 perlite/vermiculite medium and placed under intermittent mist in a shaded greenhouse.

Both oak species produced ca. 20 emergent buds per meter of branch segment, of which slightly more than half developed into sprouts that could be harvested as softwood or semi-woody cuttings. Branch segments of white oak were less sensitive to the forcing environments than branch segments of northern red oak. The water-daily-with-flooding and mist-daily-with-flooding treatments produced the lowest number of epicormic sprouts for both species. Intermittent mist produced sprouts over a longer time than the other forcing environments. The humidity domes were not tall enough to accommodate the episodic growth pattern of either oak species. Large differences were found among trees in number of emergent buds on branch segments from both white and northern red oak. None of the softwood cuttings of white oak rooted. Only semi-woody leafy cuttings of northern red oak treated with a 5 percent Dip 'n Grow solution rooted.

PHYSIOLOGICAL RESPONSES OF THREE BOTTOMLAND HARDWOOD SPECIES TO ALTERNATING PATTERNS OF FLOODING AND DROUGHT STRESS

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In recent years, much has been made of the reforestation problems encountered in the lower Mississippi Valley. Most of the region was cleared earlier in the century for agricultural purposes. The areas available for reforestation are economically marginal agricultural land and are predominately occupied by shrink-swell clays. Newly planted seedlings have small root systems that place them in danger of drought stress during the summer months. This study was undertaken to determine which commonly planted flood-tolerant bottomland species are most adapted to coping with drought stress experienced during most reforestation attempts.

The study was conducted on the campus of Stephen F. Austin University in Nacogdoches, TX. The three species selected were green ash (*Fraxinus pennsylvanica* Marshall), overcup oak (*Quercus lyrata* Walter), and Nuttall oak (*Quercus nuttallii* Palmer). Bareroot seedlings (1-0) of each species were potted and allowed to grow until June. Ten seedlings of each species were placed in water to a depth of 2.5 cm above the root collar. After 2 weeks, the flooded seedlings were removed from the water and allowed to dry for 2 days. Then the seedlings were subjected to 2 weeks of drought stress while the control seedlings continued to be watered twice daily. Physiology readings taken included stomatal conductance (G_w), transpiration (E), and leaf water potential (R).

During the flooding phase of the experiment, green ash had significantly greater G_w readings than overcup and Nuttall oak at 1000 and 1500 hours. However, Nuttall oak had significantly greater G_w readings during the drought stress phase. Nuttall oak seedlings exposed to the combination of flooding and drought stress treatments exhibited greater G_w, E, and R readings than drought-stress-only seedlings. Measurements from Nuttall oak seedlings exposed to the combination of the treatments were identical to those from control seedlings. These results indicate Nuttall oak may be better suited for reforestation in the lower Mississippi Valley than the other species evaluated.

PLANTING NORTHERN RED OAK IN THE LAKE STATES

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Regeneration of northern red oak (NRO) in the Lake States is important for timber, wildlife, and diversity. However, NRO is difficult to regenerate either naturally or artificially. We have had success planting NRO where forest managers have been willing to spend more time, effort, and money than in the past. The following factors must be considered to ensure successful regeneration. The complete details of these factors are beyond the scope of this abstract but are available from the author.

First, the manager must plan, outline objectives, and make commitments of time and money. Then, a strategy must be outlined in advance so silvicultural and wildlife considerations can be coordinated. Site selection is important, and the forest habitat type must be carefully considered. Site preparation is essential including understory control and overstory manipulation. Quality stock should be planted with adequate caliper, large dormant buds, and number of lateral roots. Container stock can be successfully used in some cases. Spring is the best time for planting, and auger planting is recommended. Weed control during establishment is necessary, and herbivore protection with shelters or fencing is recommended in areas with large numbers of browsing animals. Because frost is an important factor in the Lake States, at least 50 percent crown cover should be maintained until the oak saplings are above the temperature inversion layer in the stand. Then, the stands can be thinned to 10 trees per acre, thereby leaving mature trees for microenvironmental control and for wildlife and aesthetic purposes. Once established, NRO will persist and eventually become dominant in the overstory.

SURVIVAL AND EARLY GROWTH OF 1-0 AND 2-0 NORTHERN RED OAK SEEDLINGS UNDERPLANTED IN RED PINE PLANTATIONS

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Success of artificial oak regeneration in the northern Lake States is greatly influenced by microenvironmental conditions and deer browsing. Regeneration successes in hardwood stands have been unreliable. Significant problems are related to seedling size at planting, understory competition, late spring and early summer frosts, and deer browsing. Red pine plantations, on the other hand, provide favorable conditions for the regeneration of northern red oak. The thick layer of pine needle duff and the closed overstory canopy of red pine plantations can limit and sometime eliminate understory vegetation commonly present in hardwood stands. The pine overstory canopy also eliminates or decreases the amount of convective cooling that contributes to late spring and early summer frosts in the Lake States.

Northern red oak seedlings of two age classes (1-0 and 2-0) from the same seed lots were outplanted at four red pine plantations in northern Wisconsin. The red pine plantations were thinned to 75 percent stocking level in the winter of 1991-1992, 1-0 seedlings were planted in May 1992, and 2-0 seedlings were planted in May 1993. All four stands were thinned again in 1997 to 50 percent crown cover. All four sites were enclosed with a 2.4-m high woven wire deer exclosure, and additional 1-0 seedlings were planted inside and outside the fence to evaluate the impact of deer browsing.

Seedling survival in 1998 was greater than 92 percent at all sites for seedlings of both age classes. There were no significant differences in height growth with regard to seedling age class at the end of the 1993, 1994, 1996, and 1998 growing seasons. Average 7-year growth for 1-0 seedlings was 128 cm, and the 6-year growth for the 2-0 seedlings averaged 143 cm. In 1998, the average total height was 143 cm for the 1-0 seedlings and 158 cm for the 2-0 seedlings. It should be noted that the 1-0 seedlings were in the field for one more growing season than the 2-0 seedlings, indicating that they had a slower growth rate during the first two years. This slower growth rate was not significant in this study, but may be detrimental in hardwood outplantings where understory competition is more prevalent and likely to outgrow slower growing seedlings in the first year.

Survival of the additional 1-0 seedlings planted inside the fenced areas ranged from 95 percent to 93 percent across the four sites. Seedling survival outside the fenced areas ranged from 83 percent where the estimated deer herd density was 6 per square kilometer (14 per square mile) to 12 percent at the site where the density was approximately 31 deer per square kilometer (80 per square mile). Inside the fenced areas, average seedling height ranged from 120 to 175 cm across the sites, while outside the fence, heights ranged from 67 cm at the sites with the lower deer density to only 14 cm at the site where the herd density was the highest. In areas where deer populations are high, protection from browsing is necessary to regenerate northern red oak.

SUCCESS OF PLANTED NORTHERN RED OAK VARIES AMONG ECOREGIONS IN THE CENTRAL HARDWOOD REGION

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Oak planting has been suggested as one method for increasing the amount of oak in future stands. Planting oak can be especially useful when oak advance reproduction in the present stand is inadequate. This study reports the results of planting northern red oak (*Quercus rubra* L.) in the Ozark Highlands of Missouri and the Shawnee Hills and Highland Rim of southern Indiana. Northern red oak was planted beneath a shelterwood that had been thinned to 60 percent stocking. Three years after planting the remaining shelterwood overstory was removed. Northern red oak received six nursery treatments: (1) not undercut/not top-clipped, (2) not undercut/top-clipped, (3) undercut the first year in the nursery/not top-clipped, (4) undercut the first year/ top-clipped, (5) undercut both years in the nursery/not topped-clipped, and (6) undercut both years/top-clipped. Survival 13 years after planting ranged from 13 to 26 percent for Indiana and from 50 to 77 percent for Missouri, depending on treatment. In Missouri, the planted trees outgrew woody competitors; in Indiana the competitors outgrew the planted trees. Survival, per se, therefore does not ensure planted tree success. To better determine success, logistic regression analysis was used to develop dominance probabilities for planted oak. Accordingly, a planted oak was considered dominant if it attained 80 percent of the height of the competition. Dominance probabilities were higher in Missouri than in Indiana. This difference was due mainly to the rapid competitive growth of yellow-poplar and aspen in Indiana. The results emphasize the importance of recognizing variation in competition among ecoregions where oaks are to be planted.

REINTRODUCTION OF *QUERCUS RUGOSA* AND *QUERCUS CASTANEA* ON A DISTURBED SITE: EFFECT OF MICROHABITAT AND SEEDLING AGE

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Oak seedlings were planted on a disturbed site in the Ajusco Hills, south of Mexico City, to assess: (a) the effect of seedling age (1- vs. 2-year-old *Quercus rugosa* seedlings), and (b) the beneficial effect of nurse plants on seedling survival and growth in *Q. rugosa* and *Q. castanea* seedlings.

Previous studies showed that reintroduction of *Quercus rugosa* seedlings was difficult at the site, due to high seedling mortality during the dry season. This earlier research suggested a possible beneficial effect of established vegetation. To evaluate this, approximately 250 1- and 2-year-old *Q. rugosa* seedlings were planted in three patches. Half of each seedling age class was planted in the open, and the other half was planted under the shade provided by established plants. Due to the lack of 2-year-old *Q. castanea* seedlings, only 1-year-old seedlings of this species were planted. Seedling survival and growth were evaluated every 3 months from September 1996 to September 1997.

The beneficial effect of established plants on survival of 1-year-old seedlings of both species was evident, with 31 percent and 33 percent survival of *Q. rugosa* and *Q. castanea*, respectively, under shade vs. 7 percent and 15 percent survival, respectively, in open conditions. The importance of nurse plants decreases with time, because no significant differences in survival of 2-year-old seedlings of *Q. rugosa* were detected between shaded (37 percent) and open (42 percent) conditions. Under shade, there were no differences in survival between 1- and 2-year-old seedlings of *Q. rugosa* (31 percent vs. 37 percent, respectively), but in the open, seedling age was relevant (42 percent vs. 7 percent survival, respectively). As for growth, in neither case was there a net increase in mean seedling height after a year, due to high herbivory levels and dieback, which are common during the dry season. Regrowth during the following rainy season did not completely compensate for the loss in seedling height.

LARGE-SCALE ARTIFICIAL REFORESTATION OF OAKS ON FORMER AGRICULTURAL LAND IN THE LOWER MISSISSIPPI ALLUVIAL VALLEY

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In the lower Mississippi alluvial valley, reforestation of large tracts of former agricultural land has attracted much interest. Federal cost-share programs, which support these reforestation efforts, have contributed to this interest. A major emphasis is to introduce *Quercus* on these sites. Although information exists on the silvics of individual bottomland hardwood species, there are no data on expected survival and growth rates for this type of large-scale artificial reforestation.

Most of the research conducted on the survival and growth of artificially established bottomland oaks has been done using small-scale (less than 1 acre) plots. This study was designed to track survival and growth of Nuttall oaks (*Quercus nuttallii* Palmer) that were established on a former farmed wetland. The site chosen was indicative of lands being offered for large-scale reforestation under Federal cost-share programs such as the Wetland Reserve Program. In the winter of 1995, four reforestation treatments were established on 20-acre plots. Each treatment was replicated three times on the site. The techniques tested were (1) direct-seeded Nuttall oak acorns; (2) planted 1-0 bareroot Nuttall oak seedlings; (3) cottonwood nurse crop establishment, followed by Nuttall oak seedling underplanting in the winter of 1997; and (4) control (no artificial reforestation). All sites were prepared by disking. Post-establishment weed control by disking was done only in the cottonwood treatment for the first two growing seasons. After three growing seasons, no oak species were found in the control areas. Survival of planted oak seedlings (63 percent) was significantly greater than that of the acorn germinants (8 percent). This difference resulted in 198 stems per acre for planted seedlings and 89 stems per acre for direct-seeded plots. The cottonwood nurse crop had an average of 95 percent survival, which was expected under the intensive establishment practices used, including site-specific clones, weed control, and fertilization. Nuttall oak seedlings interplanted between the cottonwood nurse crop averaged 70 percent survival after one growing season. These results support a need for examining alternative establishment practices, including using seedlings over seed and establishing a nurse crop over open-field plantings.

LIGHT LEVELS AND NUTTALL OAK SEEDLING PHYSIOLOGY BENEATH AN EASTERN COTTONWOOD NURSE CROP

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A silvicultural system involving the use of eastern cottonwood (*Populus deltoides* Bartr. ex Marsh.) as a nurse crop for the establishment of other bottomland hardwood species is currently under evaluation as a reforestation method on marginal farmland in the Mississippi River alluvial floodplain. Cottonwood may be a suitable nurse crop for species such as Nuttall oak (*Quercus nuttallii* Palm.) because of its ability to grow on similar sites, relatively open crown form, and economic value. Yet, it is not known how shade-intolerant species such as Nuttall oak will perform when planted beneath the nurse crop. This study was established to (1) describe the photosynthetic and transpirational light responses of Nuttall oak seedlings interplanted beneath an eastern cottonwood nurse crop, (2) determine the morphological response of the interplanted Nuttall oak seedlings (specifically biomass accumulation patterns), and (3) relate physiological and morphological responses to growth of the interplanted Nuttall oak seedlings.

To establish the nurse crop plantation, eastern cottonwood clones were planted in three 5-acre replicates on marginal farmland in Sharkey County, MS, in March 1995. Cuttings were planted on a 12 x 12 ft spacing, and the plantation received mechanical cultivation for 2 years. Following the second growing season (winter 1996/1997), 1-0 Nuttall oak seedlings were interplanted between every other cottonwood row. During the establishment year, we measured photosynthetic light response, transpiration, biomass accumulation, height growth, and diameter growth on the interplanted oak seedlings. These same variables were concurrently measured on Nuttall oak seedlings planted in an adjacent open area.

Nuttall oak seedlings established beneath the eastern cottonwood canopy developed leaves with the capacity to capture available light and support positive photosynthesis. Light saturation levels and maximum photosynthesis rates of interplanted Nuttall oak seedlings were similar to those of open-grown seedlings. Measured light levels beneath the 3-year-old cottonwood canopy were about 44 percent of light available in the open. This light level appeared to be well above the light compensation point of Nuttall oak leaves, but it was just below saturating light levels. In agreement with results from physiological sampling, biomass accumulation patterns indicated that interplanted Nuttall oak seedlings were not receiving saturating light levels. Open-grown seedlings were almost 60 percent larger in mass than interplanted seedlings. The light environment beneath a 3-year-old eastern cottonwood nurse crop was adequate for maintaining positive seedling growth during the establishment year for interplanted Nuttall oak seedlings.

EFFECTS OF SIMULATED FOREST OPENINGS (MODIFIED SHADEHOUSE) ON CHERRYBARK OAK SEEDLINGS

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A key to successful oak regeneration is providing adequate light for seedling growth and development. In a forest opening, oak seedlings may receive full sunlight for some time during a day and be shaded for the remaining time. This cumulative light, or light budget, probably determines the success of oak regeneration. We designed modified shadehouses to simulate light conditions in forest openings. Three shadehouses with 80 percent shade cloth were designed to create five treatments: morning-sun (55-64 percent direct sunlight), noon-sun (26-27 percent), afternoon sun (64-73 percent), full-sun (100 percent), and no-sun (0 percent). Cherrybark oak (*Quercus pagoda*) seedlings were planted in April 1997.

After the first growing season, seedling height in the noon-sun and no-sun treatments was significantly greater than that in the other plots. There were no differences among the other treatments. Ground line diameter in the noon- and full-sun treatments was greater than in the other treatments. Leaf area with the no-sun treatment was significantly greater than that with full-sun and morning-sun treatments, but there were no differences among the other treatments. Although leaf area was greatest with the no-sun treatment, leaf dry weight per unit area (g/cm^2) for this treatment was the least. Leaf dry weight per unit area was the most for the full-sun seedlings, and there were no differences among the remaining treatments.

Banquet Presentation

CONSERVATION OF CALIFORNIA'S OAK WOODLANDS

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California's oak woodlands cover almost 10 million acres. These areas are the most biologically diverse, broad habitat in the State and are used by more than 330 terrestrial vertebrate wildlife species. Other public values supplied by oak woodlands include aesthetics, recreation, and watershed protection. Over 85 percent of these lands are privately owned, and ranchers supply most of these open space values.

Over the past 60 years, oak woodlands have faced several impacts that threaten their capacity to supply environmental values. From the post World War II period through the early 1970's, 1 million acres of oak trees were cleared as part of range improvement practices to increase the forage base for domestic livestock grazing. In the 1970's and 1980's, firewood harvest, coupled with poor oak regeneration, resulted in a further decline in oak woodland habitat. In recent years, rapid urbanization of oak woodlands, as a result of population increases of almost 2 percent annually, has further converted woodlands and fragmented remaining patches.

Beginning in 1986, the University of California, the California Department of Forestry and Fire Protection, and the California Department of Fish and Game have been partners in the Integrated Hardwood Range Management Program (IHRMP). The IHRMP has developed research and education tools to be used to conserve the State's oak woodlands. IHRMP activities have brought about a decrease in exploitive oak tree harvesting practices, and improvement in the success of oak planting programs, the development of locally based best management practices to sustain woodland values, and incorporation of oak woodland habitat considerations into local land-use planning.

Future conservation efforts will need to build upon local conservation strategies that are science-based, to ensure that the important public values of oak woodlands can be sustained as population increases in the State continue to escalate.

Summary

CALIFORNIA OAK FIELD TRIP

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The Lake Tahoe Basin, where our meeting was held, is not a particularly good location to observe native California oaks because at over 6,000 feet it is outside the natural range of all but huckleberry oak, a shrub species that grows in alpine areas. So our field trip to see oak forests had to take us over the Sierra summit and down towards the Central Valley into lower elevation hardwood rangelands. We began driving around the west shore of Lake Tahoe through some spectacular scenery. Emerald Bay, the Kaiser Estate (and the house where portions of *The Godfather* were filmed), the encampment of the Donner Party and Squaw Valley, and the site of the 1960 Winter Olympics were just a few of the sites we observed and talked about along the way. Our first stop was in Bear Valley, the site of a beautiful nature trail developed by the Pacific Gas and Electric Company. Here we saw California black oak, an important component of a vegetation type in the State known as mixed conifer forest. Bear Valley is at approximately 5,000 feet and towards the upper end of the range of black oak, so most of the trees we saw were not the best examples of this species. However, regardless of size or form, black oaks are very important from a wildlife habitat standpoint, because these trees provide not only mast and browse for migrating deer herds, but also food, cavity nest sites, and thermal and hiding cover for a wide range of other wildlife species.

Our next stop took us further down the Sierra slopes to a thinning project in the Tahoe National Forest. Here USDA Forest Service silviculturalist Don Thane described how they were trying to protect critical habitat for California spotted owls by thinning surrounding stands and creating a shaded fuel break to protect owls from fire. The thinned stand we walked through consisted almost exclusively of black oak and Pacific madrone, which the Forest Service is committed to maintaining in the forest because of their high value for wildlife. These stands had originated a little over a century ago after either a wildfire or harvest, and most trees were obviously of sprout origin because they had multiple stems. The current thinning had occurred only about 4 months earlier, but already most of the black oak stumps had many 2-foot-tall sprouts, some of which had been browsed by deer. These vigorous new sprouts were in stark contrast to the small several-inch-tall oak seedlings we saw interspersed among the trees. These seedlings appeared to have languished on the forest floor for a decade or more with negligible aboveground growth. By digging down a way, however, we found that most had sizable root systems. Now that these stands have been opened up, these seedlings will have a much better chance to "take off" and become established.

As we continued down through the foothills to lower elevations, the oak species changed. Between 3,000 and 4,000 feet, we passed through a band of canyon live oak. At about 3,000 feet, this species faded, to be replaced by blue oak and interior live oak, although black oak was still evident in some areas. A little further down, around 2,000 feet elevation, the black oak disappeared, but we began to see some majestic valley oaks, especially along the riparian areas that the highway passed through. Outside of these riparian areas, however, everything was much drier. The understory consisted largely of dead and brown introduced Mediterranean annual grasses that provide the

distinctive golden color to so much of the State's rolling hills. As we had heard in some earlier presentations, competition from these non-native plants is thought to be partially responsible for poor natural regeneration of several native California oak species.

Our next stop was at a hardwood lumber mill in Auburn, CA, called California Hardwood Producers. The proprietor, Dave Parmenter, explained how this was one of the few mills in the State devoted exclusively to hardwoods. Despite a devastating fire at the mill a little over a year ago that destroyed virtually all of their buildings and most of their wood and logs, they were still in business, had built up their inventory, and couldn't keep up with the demand for most of their products. The key to being successful, Dave explained, was to maximize production of the higher grade materials, while also using lower grades for a variety of products. As a result, the mill produced everything from firewood to pallet stock to railroad ties to fine flooring and cabinet lumber. As the group was about to leave, we toured the office and saw some impressive examples of beautiful wood products made from a variety of California hardwoods. The commercial hardwood industry in California is still in a fledgling state, so there is clearly great promise yet to be realized.

Leaving Auburn we entered the American River Canyon. Some of the surrounding hills were completely covered with chaparral, which had replaced the native trees following a relatively recent fire. On the north slopes heading out of the canyon, however, the canopy was extremely dense, consisting mainly of interior live oak, with occasional black oak, canyon live oak, foothill pine, and ponderosa pine. Passing through the town of Cool, CA, we saw examples of excellent natural regeneration of blue and valley oak, species in California that are reported to be regenerating poorly in many locations. We also saw some magnificent mature valley oaks—some nearly 6 feet in diameter. A few miles down the road we stopped at the site of a small vineyard that had been installed in the past year. Mark Hicks, a project manager with the local Resource Conservation District, explained how increasing development and agricultural conversions in the foothills were impacting values associated with oak woodlands, specifically wildlife habitat. As a result, the county had formed an Oak Woodlands Advisory Committee to evaluate impacts and assess the long-term need for conservation measures. While developments and conversions are likely to continue in the future, negative impacts can be minimized by landscape-level planning aimed at preserving woodland values such as wildlife habitat and rural ambiance that occur at a landscape scale. To offset losses that do occur, the committee is recommending replacement of habitat, including planting of oaks at sufficient density to provide adequate canopy cover.

We ended the field tour at the town of Coloma, CA, and the Marshall Gold Discovery State Historic Park. This year is the sesquicentennial celebration of the 1848 discovery of gold in California, which occurred about 200 yards from where we ate lunch. After eating under the canopies of a variety of native and exotic hardwoods, we were treated to a very humorous and informative talk by a Park docent. He explained how James Marshall happened to be in Coloma in 1848 building a sawmill for John Sutter, how and where the first gold nugget was found, and how this discovery transformed the Coloma settlement and the entire State of California forever. The tour ended with a sawmill demonstration using an exact replica of the sawmill James Marshall constructed 150 years ago. The day ended too soon and we were sorry to climb back aboard the tour bus and return to South Lake Tahoe, but all in all, it had been a great field tour.

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U.S. Department of Agriculture, Forest Service.
1999. McCreary, D.D.; Isebrands, J.G., eds. **Seventh workshop on seedling physiology and growth problems in oak plantings (abstracts)**; 1998 September 27-29; South Lake Tahoe, CA. Gen. Tech. Rep. NC-206. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 18 p.

Research results and ongoing research activities in field performance of planted trees, seedling propagation, physiology, genetics, acorn germination, and natural regeneration for oaks are described in 17 abstracts.

KEY WORDS: Plantations, propagation, regeneration.

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Our job at the North Central Forest Experiment Station is discovering and creating new knowledge and technology in the field of natural resources and conveying this information to the people who can use it. As a new generation of forests emerges in our region, managers are confronted with two unique challenges: (1) Dealing with the great diversity in composition, quality, and ownership of the forests, and (2) Reconciling the conflicting demands of the people who use them. Helping the forest manager meet these challenges while protecting the environment is what research at North Central is all about.